Fluidization and discharge of cohesive powders

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SUMMARY

The interparticle forces in cohesive powders can influence their flow properties negatively. This may cause great problems in processes involving cohesive powders. In this study the influence of the cohesiveness of a powder on fluidization and the discharge from silos is determined.
Fluidization of cohesive powders is very difficult due to the formation of channels in the bed, as soon as the air flow rate is raised above the point of minimum fluidization. These channels provide preferential paths for the upward flowing air, thereby greatly reducing the fluid-like behaviour, that is characteristic for a well fluidized bed. The formation of channels can be suppressed by applying vibration to the bed.
The discharge of cohesive powders from silos can be very troublesome because of the formation of flow obstructions (arching and piping). Similarly to fluidization it is possible to increase the flowability of a cohesive powder using combined aeration and vibration.
In this thesis use has been made of a cylindrical silo (diameter 0.288 m), with a flat gas permeable bottom as gas distributor. This bottom could be vibrated. In a central opening orifices of different sizes could be mounted.
After a general introduction in chapter 1, chapter 2 begins with the study of the discharge of a non-cohesive powder (glass ballotini) from a silo (orifice diameter 3 - 18 mm) under the influence of gravity. A varying air flow rate was then introduced into the silo through the gas distributor and the resulting discharge, partly pneumatic and partly gravitational, was studied.
The powder flow rate could be described by a relationship in which the driving force for discharge consists of a gravitational term and a term including the pressure drop over the orifice. If the gravitational term is small compared to the pressure term, gravity may be neglected, giving a somewhat simpler relation.
A proper understanding of the mechanical behaviour of a simultaneously aerated and vibrated particle bed is essential for the description of powder discharge from a silo using combined aeration and vibration. A model for the mechanical behaviour of a particle bed is developed in chapter 3. The powder bed was assumed to have a constant porosity, and wall friction was neglected. From this model it was found that for certain aeration and vibration conditions the powder bed dislodges from the vibrating gas

distributor temporarily. The formation of an air gap between the bed and the bottom plate gives rise to extra forces acting on the powder bed, that can greatly influence the behaviour of the bed.

A comparison of the developed model with experimental results is made in chapter 4. There appeared to be a difference between theory and experiments. This discrepancy could largely be resolved by the introduction of an empirical correction factor for a varying porosity in the bottom part of the bed. This correction accounts for the deviation in the drag forces acting on the powder in this region of the bed if the voidage here does not remain constant.

The strength of a cohesive powder depends on the degree of consolidation. The cohesion can be influenced by the moisture content of a powder. Use was made of this to vary the cohesiveness of native potato starch in a controlled manner. In chapter 5 the flow properties of potato starch with different moisture contents under a varying consolidation load were determined using a triaxial cell. It was found that the potato starch gained strength with increasing consolidation load and increasing moisture content in the range 6 - 25% (weight percentage on dry solids basis).

The influence of the cohesiveness of a powder on the fluidization behaviour was studied in chapter 6. From experiments it appeared that a slightly cohesive powder (glass ballotini) could be fluidized well, whereas a more strongly cohesive powder (native potato starch) could not be fluidized. Fluidization of the cohesive potato starch was possible when vibration was applied to the gas distributor. The vibration intensity required to obtain a well fluidized bed depended on the moisture content of the potato starch. For higher levels of moisture content a larger vibration amplitude was necessary at the same vibration frequency. When keeping the maximum vibration acceleration constant it was found that low frequencies were more effective in improving the fluidization quality in the range studied (30 - 90 Hz).

Discharge of a cohesive powder can be improved by the combined use of aeration and vibration. In chapter 7 this was done for native potato starch with a varying moisture content. It was shown experimentally that the combination of aeration and vibration is more effective in facilitating the powder flow than when aeration or vibration were applied separately. The formation of channels caused by aeration is reduced by vibration, while the consolidating effect of vibration is suppressed by aeration.

Minimum aeration and vibration levels necessary to provide a regular discharge were determined. These aeration and vibration rates increased with increasing moisture content of the potato starch powder and decreasing orifice size. As in the case of fluidization it was found that for a constant maximum vibration acceleration a lower frequency, in the range 30 - 90 Hz, was most effective in facilitating the discharge.

An explanation for the higher effectiveness of lower frequencies for improvement of fluidization and discharge are the higher impact forces that arise when the powder bed collides with the bottom plate after a period of flight.

The rate of discharge of a cohesive powder from a silo using aeration and vibration could be described reasonably well by a relationship similar to that for the discharge of non-cohesive powders with aeration but without the aid of vibration.